United States Patent [19]

Sugano et al.

[11] **3,819,296**

[45] **June 25, 1974**

[54] **CONTROL FOR HYDRAULIC MACHINE HAVING ADJUSTABLE BLADES**

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[22] Filed: **Mar. 6, 1972**

[21] Appl. No.: **232,090**

[52] **U.S. Cl.** **416/157**

[51] **Int. Cl.** **B63h 3/02**

[58] **Field of Search** 416/157, 45–48, 416/157, 154, 162

[56] **References Cited**

UNITED STATES PATENTS

1,723,617	8/1929	Hele-Shaw et al.	416/157
2,686,569	8/1954	Bruce	416/157
3,228,480	1/1966	Jorgensen	416/157
3,229,771	1/1966	Hedberg	416/157
3,242,992	3/1966	Quenneville et al.	416/157
3,261,406	7/1966	Goodman et al.	416/157 UX
3,459,267	8/1969	Chilman	416/157
3,528,752	9/1970	Davies et al.	416/157 X
3,597,107	8/1971	Schegolev et al.	416/157 X
3,603,698	9/1971	Jensen	416/157
3,676,016	7/1972	Feroy	416/157
3,692,041	9/1972	Bondi	137/246.12 X

FOREIGN PATENTS OR APPLICATIONS

720,239	10/1965	Canada	416/157
1,112,411	11/1955	France	416/157
1,260,746	4/1961	France	416/157
2,027,824	12/1970	Germany	416/157

Primary Examiner—Everette A. Powell, Jr.

Attorney, Agent, or Firm—McGlew and Tuttle

[57] **ABSTRACT**

The pitch of blades in a fan is varied by means of a hydraulic servo mounted in the runner. A pilot valve controls a supply of oil under pressure to the hydraulic servo. The casing of the pilot valve is mounted to the blade actuating member of the hydraulic servo. The casing is preferably made integral with either the cylinder or the piston of the hydraulic servo.

8 Claims, 8 Drawing Figures

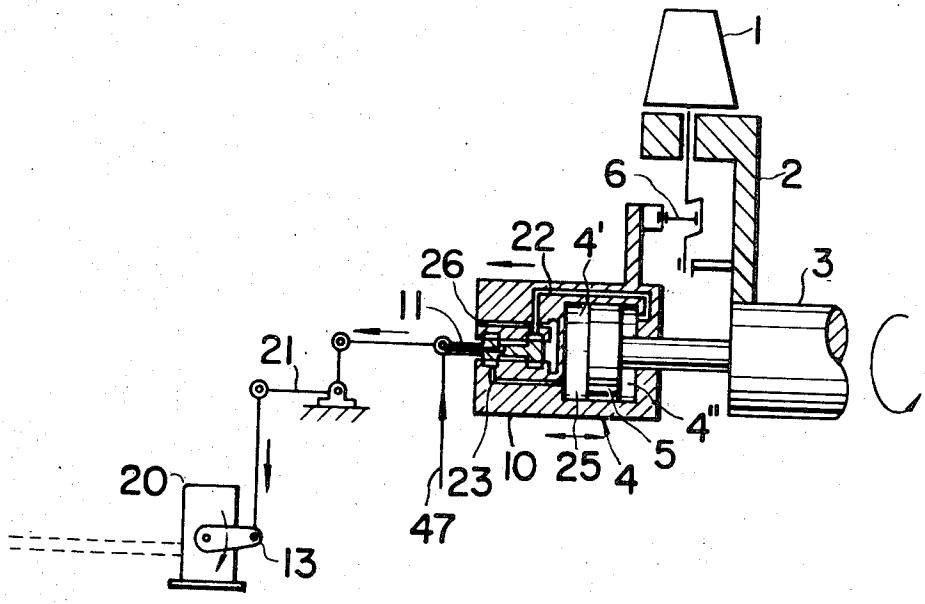


FIG. 1 PRIOR ART

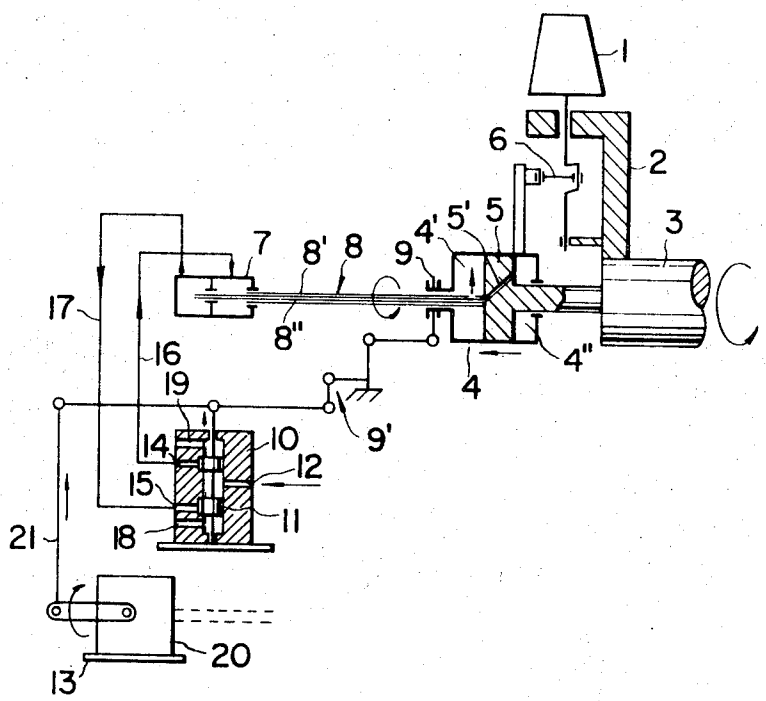


FIG. 2

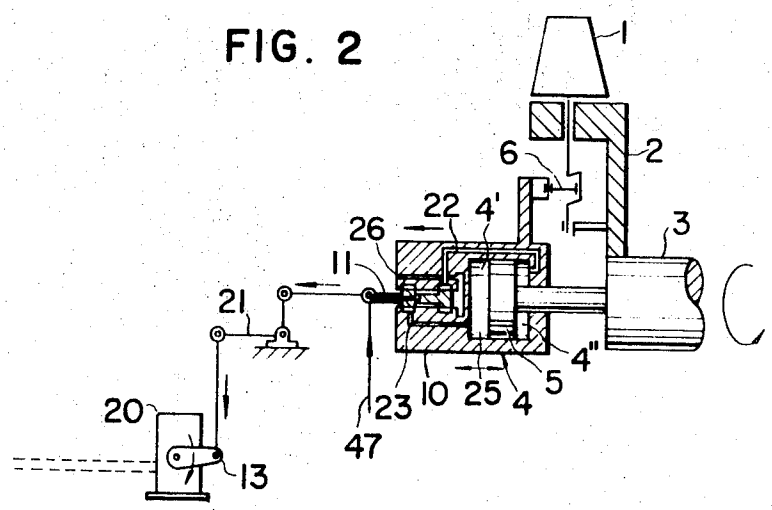


FIG. 3

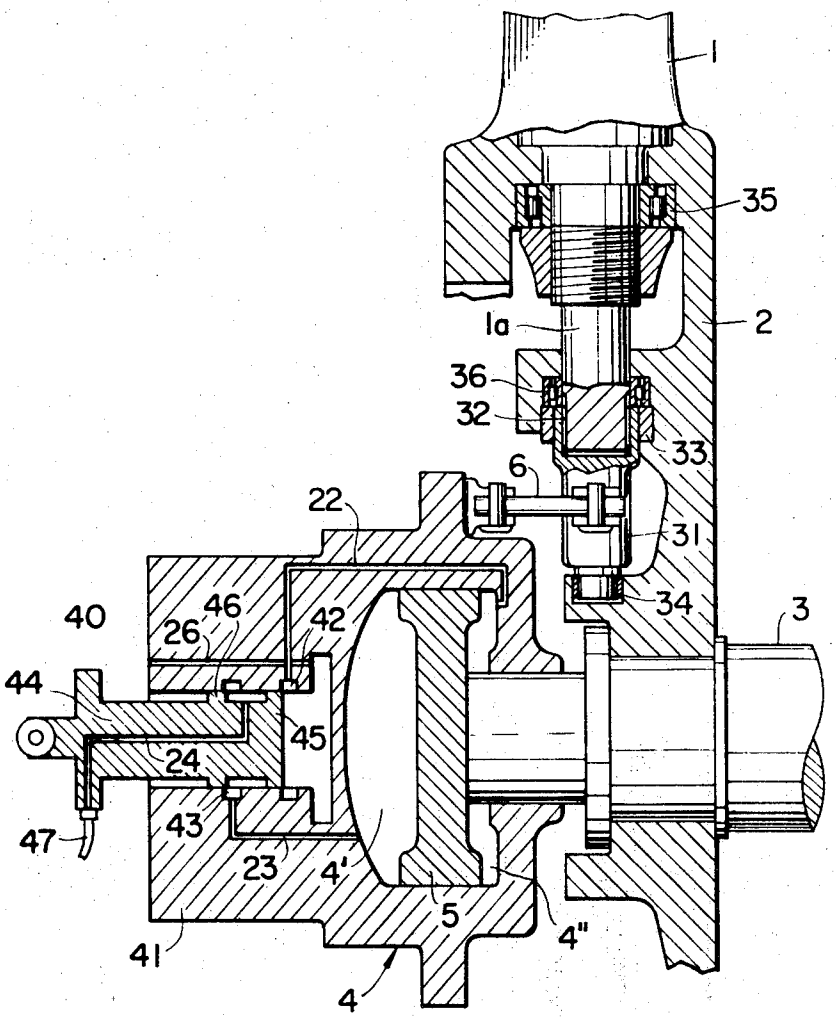


FIG. 4

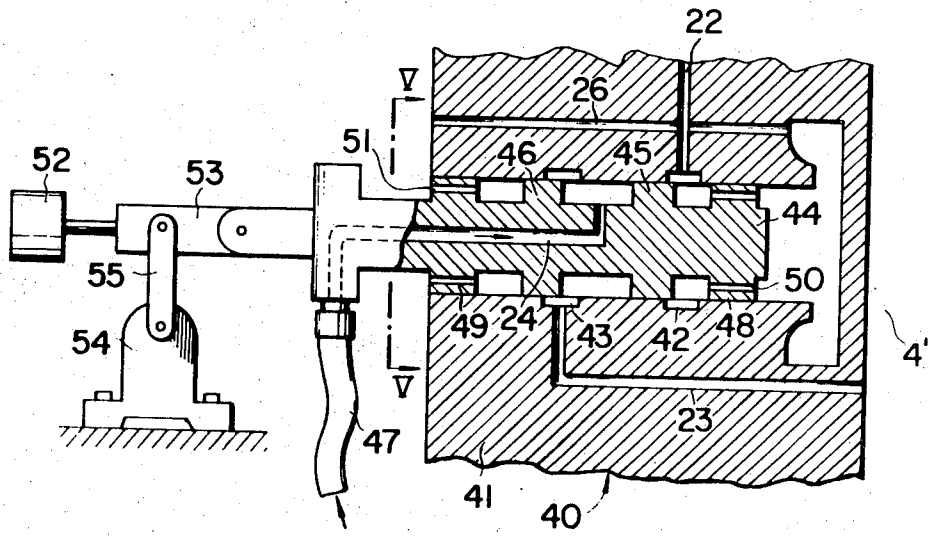


FIG. 5

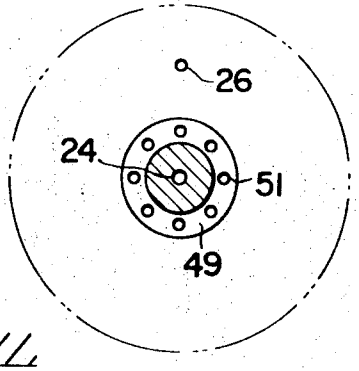
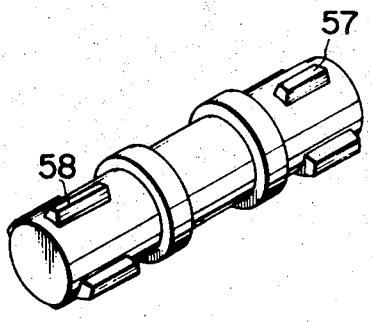


FIG. 6



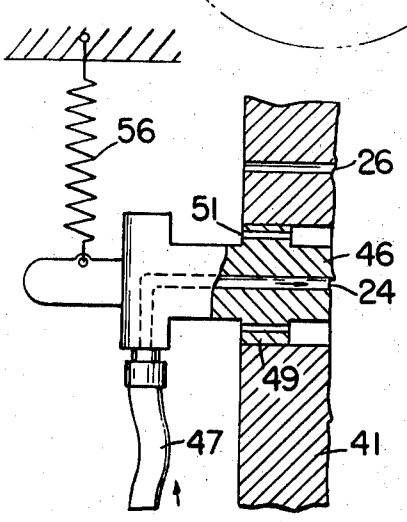
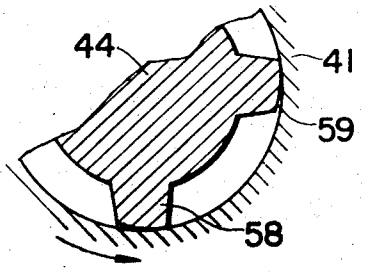


FIG. 8

FIG. 7



CONTROL FOR HYDRAULIC MACHINE HAVING ADJUSTABLE BLADES

BACKGROUND OF THE INVENTION

The present invention relates to hydraulic machines having adjustable blades and more particularly to a hydraulic control system for an axial fan having adjustable blades.

A prior control system is illustrated in FIG. **1.**

A runner **2** on the rotating shaft **3** of an axial fan is provided with a plurality of blades **1** only one of which is shown. The blade may be adjusted in the following manner:

When a drive unit **20** receives a command signal, the lever of the drive unit **20** swings in the direction indicated with arrow to move upwardly the spool **11** of a pilot valve **10** through a linkage **21** so that an inlet port **12** of the pilot valve **10** comes into communication with a first outlet port **14.** Oil under pressure from the inlet port **12** is now admitted to the right-hand chamber of an oil intake box **7** through a passage **16** and flows through the annular space between the outer pipe **8'** and the inner pipe **8''** of a coaxial pipe assembly **8** installed in the shaft **3** and enters the left-hand chamber **4'** of a movable cylinder **4** slidably fitted on a piston **5** of a hydraulic servo secured to the shaft **3** so that the cylinder **4** moves leftwardly. The leftward movement of the cylinder **4** is transmitted to the blade **1** through a linkage **6** thereby varying the pitch of the blade **1.** The oil in the right-hand chamber **4''** of the cylinder **4** in then exhausted through a passage **5'** in the piston **5,** the inner pipe **8'',** the left-hand chamber of the oil intake box **7,** a passage **17** and a second outlet port **15** and an exhaust port **18.** The leftward movement of the cylinder **4** is also transmitted through a return mechanism **9** and a linkage **9'** to the spool **11** thereby returning the spool **11** in the pilot valve **10** to its neutral position so that the pitch of the blade **1** is held at a predetermined value.

In the above construction, since the pilot valve **10** is stationarily installed, for example, in the casing of a fan, the oil intake box **7** as well as the coaxial pipe assembly **8** must be provided for supplying oil from the stationary pilot valve **10** to the cylinder **4** rotating together with the shaft **3.** In addition a return system **9, 9'** is required for feeding back the movement of the cylinder **4** to the spool **11** of the pilot valve **10.** This results in a complicated structure. Further a play in the return system **9, 9'** as well as any oil leakage in the oil intake box **7** will cause a delay in response.

SUMMARY OF THE INVENTION

The principal object of the invention is to overcome the above difficulties.

Another object of the invention is to provide a simple and compact hydraulic control system for adjustable blades of a fan without delay in response.

In accordance with the invention, the casing of the pilot valve is mounted to the cylinder of the hydraulic servo. In this case the cylinder is linked to the blades while the piston slidably fitted in the cylinder is secured to the fan runner.

In a modification, the cylinder of the hydraulic servo is secured to the fan runner, and the piston slidably fitted in the cylinder effects adjustment of the blades. The casing of the pilot valve is then mounted to the piston.

Other objects and the features of the invention will become apparent from the following description and drawings.

BRIEF DESCRIPTION OF THE DRAWING

In the accompanying drawings:

FIG. **1** illustrates schematically a prior control system for an axial fan,

FIG. **2** shows schematically a control system embodying the invention,

FIG. **3** is an enlarged view of a part of FIG. **2,**

FIG. **4** is a view of another embodiment similar to FIG. **3,**

FIG. **5** is a sectional view taken along the line V—V of FIG. **4,**

FIG. **6** shows a modified spool of the pilot valve, and

FIG. **7** shows a cross section of the spool in FIG. **6.**

In the Figures throughout, like reference characters refer to similar parts.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to FIGS. **2** and **3,** a runner **2** secured on the shaft **3** of an axial fan is provided with a plurality of adjustable blades **1** only one of which is shown. The blade **1** is rotatably fitted at its pivot **1***a* in the runner **2.** The free end of the pivot **1***a* is coupled with the shaft **31** of a crank mechanism through splined engagement **32** so that the pivot **1a** and the crank shaft **31** are axially movable relative to each other and rotate together. The crank shaft **31** is also supported at its upper and lower ends in the runner **2** by means of oilless bearings **33** and **34.** A thrust bearing **35** serves to take axial thrust of the blade **1,** and another thrust bearing **36** is provided for taking axial thrust of the crank shaft **31.** Thus the centrifugal force acting on the blade **1** may be taken independently of that acting on the crank shaft **31.** In addition the pivot **1***a* is relieved of a bending moment due to the force acting on the crank shaft **31.**

In order to vary the pitch of the blade **1,** there is provided a hydraulic servo consisting of a piston **5** secured to the end of the shaft **3** and a cylinder **4** slidably fitted on the piston **5.** The piston **5** defines a left-hand chamber **4'** and a right-hand chamber **4''** in the cylinder **4.**

A pilot valve **40** is provided for controlling a supply of oil under pressure to the cylinder **4** of the hydraulic servo. The casing **41** of the pilot valve **40** is formed integral with the cylinder **4.** Thus the valve casing **41,** the cylinder **4** and the piston **5** rotate together with the shaft **3** of the fan. The valve casing **41** has a port **42** leading through a passage **22** to the right-hand chamber **4''** of the cylinder **4** and another port **43** leading through another passage **23** to the left-hand chamber **4'.** A spool **44** loosely fitted in the valve casing **41** has lands **45** and **46** capable of covering the ports **42** and **43** respectively. An oil inlet passage **24** formed in the spool **44** opens to the stem between the lands **45** and **46** and is supplied with oil under pressure through a pipe **47.** Upon leftward movement of the spool **44** from the its neutral position, the inlet passage **24** comes into communication with the passage **23,** while the passage **22** is brought into communication with an exhaust pas-

sage 26. On the contrary, the rightward movement of the spool 44 brings the inlet passage 24 into communication with the passage 22 and causes the passage 23 to be relieved. The valve spool 44 is linked to a drive unit 20 through a linkage 21.

When a command signal is applied to the drive unit 20, its lever swings clockwise thereby moving leftwardly the spool 44 of the pilot valve 40 from its neutral position, as shown in FIG. 3. Oil under pressure from the pipe 47 flows through the inlet passage 24, the port 43 and the passage 23 into the left-hand chamber 4' of the cylinder 4 and causes the cylinder 4 to move leftwardly. The movement of the cylinder 4 is transmitted to the blade 1 through the linkage 6, the crank mechanism 31 and the splined engagement 32 to rotate the blade 1 about its axis. The oil remaining in the chamber 4'' of the cylinder is then exhausted through the passage 22, the port 42 and the exhaust passage 26.

When the valve casing 41 which moves leftwardly together with the cylinder 4 reaches a position relative to the spool 44 at which the land 46 of the spool 44 covers the port 43, further supply of oil to the chamber 4' is cut off so that the blade 1 is now held at its adjusted position. Thus the movement of the spool 44 adjusts uniquely the pitch of the blade 1.

For the reverse adjustment of the blade 1, the spool 44 is moved rightwardly. Oil under pressure then flows through the inlet passage 24, the opening 42 and the passage 22 into the right chamber 4'' of the cylinder 4 and adjusts the blade 1 in a similar manner.

In the above structure, the casing 41 of the pilot valve 40 rotates in sliding contact with the spool 44. The lands 45, 46 of the spool 44, therefore, are liable to abrasion or seizure. This will disturb the adjustment of the blade 1.

In a modification shown in FIGS. 4 and 5, the spool 44 is formed with bearing collars 48, 49 axially beyond the lands 45 and 46, respectively. The outer diameter of the bearing collars 45, 46 is dimensioned slightly smaller than the inner diameter of of the valve casing 41 so as to leave a clearance necessary for producing a lubricating oil film between the casing and the spool. Since the collars 48 and 49 serve to keep the spool 44 in sliding contact with the valve casing 41, the outer diameter of the lands 45 and 46 may be dimensioned smaller than that of the bearing collars 48 and 49 merely in consideration of change-over performance of the spool. The bearing collars 48 and 49 are formed with a plurality of axial bores 50 and 51, respectively arranged circumferentially. A part of the oil supplied from the oil inlet passage 24 which has leaked out through the clearance between the lands 45, 46 and the valve casing 41 serves to lubricate the bearing collars 48 and 49 thereby keeping them from abrasion or seizure. The leakage oil may be exhausted through the axial bores 50 and 51. The bearing collars 48 and 49 also serve to take any unbalanced loading acting on the spool 44. However the spool 44 may not be fully relieved of unbalanced loading, particularly when the oil supply pipe 47 is connected to the spool 44. For balancing the resultant eccentric load acting on the spool 44, due to the weight of supply pipe 47, there is provided a counter weight 52 which is linked to the spool 44 through a linkage 53. The linkage 53 is supported on an abutment 54 through interposition of a lever 55. Instead of the counter weight there may be provided a spring 56 for lifting the left end of the spool 44.

In order to improve lubrication of the spool in the valve casing rotating at a higher speeds, the spool 44 may be formed on its periphery with a plurality of radial fins 57 and 58 in place of the collars 48, 49. The oil which has leaked out through the clearance between the lands 45, 46 and the valve casing 41 rotates together with the valve casing 41 so that a centrifugal force due to the rotation contributes to formation of an oil film over the whole inner surface of the valve casing 41. When each of fins 57, 58 is chamfered particularly, at its leading edge 59, a supply of lubricating oil to the sliding faces of the fin and the valve casing is improved further. This also permits the clearance between the fin and the valve casing to be reduced with while maintaining a satisfactory lubrication.

The thus constructed control system has various advantages: Since the casing of the pilot valve for controlling a supply of oil pressure to the hydraulic servo for adjusting the blades is built in the cylinder of the hydraulic servo, it is possible to omit a return mechanism for returning the movement of the cylinder to the casing of the pilot valve, and this results in a simple and compact structure of the control system. In addition, the movement of the cylinder may be returned directly to the valve casing of the pilot valve without delay in response due to play accompanied by a prior return mechanism. The valve spool which is arranged coaxially with the rotating shaft of the fan permits the casing of the pilot valve to rotate therearound in sliding relationship, whereby such means as parts 7, 8' and 8'' in FIG. 1 for conveying the oil from the stationary part of the pilot valve to the rotating cylinder may be omitted. This also results in a simple and compact hydraulic control circuit. A delay in response due to leakage of oil from the oil conveying means is excluded.

While preferred embodiments of the invention have been shown and described, it will be obvious that various modification may be made without departing from the spirit and scope of the invention.

For example, it is possible to fix a separate casing of the pilot valve to the cylinder of the hydraulic servo. It is also possible to dispose a motion transmitting means between a casing of the pilot valve and a cylinder of the hydraulic servo arranged separately from each other. In the case where the cylinder of the hydraulic servo is installed integral with the runner of the fan and the adjusting motion of the piston fitted in the cylinder is transmitted to the blades, the piston may be fixedly connected to the casing of the pilot valve. Further, in the case where the casing of the pilot valve is moved in response to an external signal, the spool thereof may be connected to the cylinder of the hydraulic servo.

What is claimed is:

1. In a hydraulic machine having a runner fixedly secured to a runner shaft for rotation therewith and blades pivotally mounted in the runner for angular adjustment about their pivot axes, a control system for adjusting said blades comprising, in combination, a hydraulic servo, including a cylinder and a piston slidable in said cylinder, rotatable coaxially with said runner; means connecting one of said cylinder and said piston to said blades for adjusting said blades, the other of said cylinder and said piston being fixed to said runner shaft; a pilot valve controlling supply of hydraulic fluid under pressure to said servo to effect relative move-

ment of said cylinder and said piston to adjust said blades; said pilot valve including a casing and a valve spool slidable in said casing coaxially with said runner; said casing being incorporated in said one of said cylinder and said piston for rotation coaxially with said runner; said valve spool being non-rotatable; respective passage means connecting the interior of said casing to said cylinder on respective opposite sides of said piston; said valve spool having a passage extending therethrough and selectively connectable to either of said passage means responsive to relative axial displacement of said valve spool and said casing; an oil supply line connected to said valve spool in communication with the passage therethrough; drive means connected to said valve spool and operable to effect relative axial movement of said casing and said valve spool to control supply of oil to opposite sides of said piston; and means connected to the axially outer end of said valve spool and serving to balance the weight of said valve spool.

2. A control system, as claimed in claim **1,** in which said valve spool is formed with bearing means spaced axially outwardly from each of said lands and engaged with said casing.

3. A control system, as claimed in claim **2,** in which each of said bearing means defines axially extending passages for flow of oil for lubrication of said pilot valve.

4. A control system, as claimed in claim **2,** in which said bearing means comprises respective bearing collars each disposed axially outwardly of a respective land; each collar being formed with passages extending therethrough parallel to the axis of said valve spool for flow of oil for lubrication of said pilot valve.

5. A control system, as claimed in claim **2,** in which said bearing means comprises respective sets of circumferentially spaced radially extending ribs on said valve spool, each set of ribs being disposed axially outwardly of a respective land.

6. A control system, as claimed in claim **5,** in which each of said fins is chamfered at the leading edge thereof.

7. In a hydraulic machine having a runner fixedly secured to a runner shaft for rotation therewith and blades pivotally mounted in the runner for angular adjustment about their pivot axes, a control system for adjusting said blades comprising, in combination, a hydraulic servo, including a cylinder and a piston slidable in said cylinder, rotatable coaxially with said runner; means connecting one of said cylinder and said piston to said blades for adjusting said blades, the other of said cylinder and said piston being fixed to said runner shaft; a pilot valve controlling supply of hydraulic fluid under pressure to said servo to effect relative movement of said cylinder and said piston to adjust said blades; said pilot valve including a casing and a valve spool slidable in said casing coaxially with said runner; said casing being incorporated in said one of said cylinder and said piston for rotation coaxially with said runner; said valve spool being non-rotatable; respective passage means connecting the interior of said casing to said cylinder on respective opposite sides of said piston; said valve spool having a passage extending therethrough and selectively connectable to either of said passage means responsive to relative axial displacement of said valve spool and said casing; an oil supply line connected to said valve spool in communication with the passage therethrough; drive means connected to said valve spool and operable to effective relative axial movement of said casing and said valve spool to control supply of oil to opposite sides of said piston; and a counterweight connected to the axially outer end of said valve spool and serving to balance the weight of said valve spool.

8. In a hydraulic machine having a runner fixedly secured to a runner shaft for rotation therewith and blades pivotally mounted in the runner for angular adjustment about their pivot axes, a control system for adjusting said blades comprising, in combination, a hydraulic servo, including a cylinder and a piston slidable in said cylinder, rotatable coaxially with said runner; means connecting one of said cylinder and said piston to said blades for adjusting said blades, the other of said cylinder and said piston being fixed to said runner shaft; a pilot valve controlling supply of hydraulic fluid under pressure to said servo to effect relative movement of said cylinder and said piston to adjust said blades; said pilot valve including a casing and a valve spool slidable in said casing coaxially with said runner; said casing being incorporated in said one of said cylinder and said piston for rotation coaxially with said runner; said valve spool being non-rotatable; respective passage means connecting the interior of said casing to said cylinder on respective opposite sides of said piston; said valve spool having a passage extending therethrough and selectively connectable to either of said passage means responsive to relative axial displacement of said valve spool and said casing; an oil supply line connected to said valve spool in communication with the passage therethrough; drive means connected to said valve spool and operable to effect relative axial movement of said casing and said valve spool to control supply of oil to opposite sides of said piston; and a lifting spring connected to the axially outer end of said valve spool and serving to balance the weight of said valve spool.

* * * * *